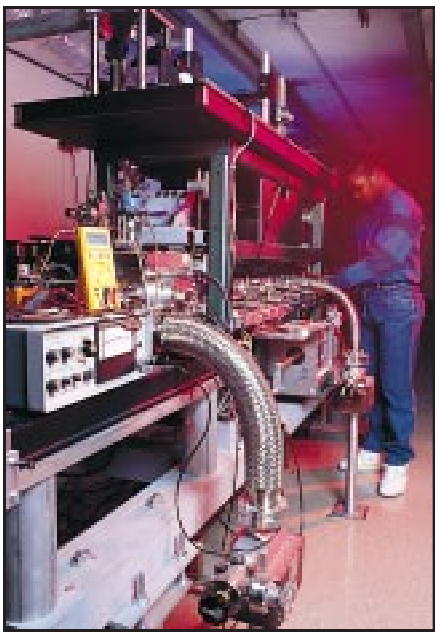
A NEW DAY DAWNS FOR REVITALIZED LASER

Once limited to the physics laboratory, the free-electron laser has found a new life as a unique tool for medical and industrial research.

In the early years of medical laser research, doctors used single-wavelength lasers with limited dynamic properties. When the free-electron laser (FEL) was developed, it offered short pulses, high peak power, and a greater range of wavelengths. Not surprisingly, this innovation yielded a host of advances in the medical field. Vanderbilt University (Nashville, TN) is a nexus of these advances.



■ A laser technician works on Vanderbilt University's free-electron laser (pictured above), which has provided major breakthroughs in mammography and neurosurgery.

During the late 1980s, Vanderbilt was one of several centers of excellence to receive funding through BMDO's Medical Free-Electron Laser (MFEL) program. The U.S. Congress conceived the MFEL program as a means to leverage and transfer technology from the military's laser research program to the medical community. Since then, the advanced capabilities of the FEL have benefited both clinicians and basic scientists, enabling dramatic progress in laser medicine, materials science, and a host of other specialties. Many research centers translated the FEL's advances into procedures that now use portable lasers such as the neodymium:YAG.

Underground vault. Vanderbilt, however, has taken a novel approach, building a multidisciplinary facility around its 75-foot-long FEL. Housed in the basement of the W.M. Keck Free-Electron Laser Center, the enormous laser is encased in a 13,000 ft^2 vault of thick concrete. A series of tubes and mirrors route the beam to the second floor of the center, which houses the FEL control room, five laser target rooms, two experimental surgical suites, and supporting biology and electronics laboratories. The arrangement encourages a free exchange of ideas among surgeons, clinicians, physicists, and biologists who are the primary beneficiaries of the FEL's presence.

The FEL program at Vanderbilt won an initial grant from the Office of Naval Research (ONR) and BMDO (then the Strategic Defense Initiative Organization) in 1987. The W.M. Keck Foundation contributed funds in 1993 to help expand the FEL facility, and ONR added more funding in 1996. Today, Vanderbilt scientists are testing the laser for a variety of clinical purposes.

For example, one primary task is generating monochromatic x-rays for mammography. According to breast cancer specialist Dr. Frank Carroll, these FEL-generated beams potentially will make tumor images "stand out like headlights," greatly enhancing a mammographer's ability to detect cancer. In addition to better image clarity, this method exposes the patient to ten times less radiation than conventional mammography. In the future, work with Los Alamos, Lawrence Livermore, and Oak Ridge National Laboratories is expected to yield a new imaging technique that uses 100 times less radiation than current x-ray technology.

Tumors beware! Vanderbilt neurosurgeon Dr. Michael Copeland says that the FEL is the best answer yet for expanding the role of lasers in neurosurgery. Carbon dioxide and erbium:YAG lasers cause too much thermal damage to be used extensively in neurosurgery, but the more precise control and tunability of the FEL may change the way surgeons regard lasers for this specialty. Deep-seated tumors previously considered inoperable may be treated more effectively with the infrared beams of the FEL. Pending approval by the U.S. Food and Drug Administration by the end of 1998, Dr. Copeland expects to perform the first human neurosurgery using the FEL.

In addition to laser medicine, the FEL can open windows into the materials world of such manmade structures as solar cells, electronic devices, and biosensors. Amorphous silicon solar cells can be bombarded with intense light to examine how and why these cells wear out over time. In the same way that the FEL interacts with the individual atoms of DNA to give molecular information, the atoms in a semiconductor can be manipulated to yield information about its electrical properties. Even the interface between living and nonliving structures can be explored to create biosensors, which are implanted silicon chips that can react to glucose, for instance, and deliver insulin in response.

In electronics, diamond substrates are another interesting topic for FEL users. For many years, researchers have worked to harness the excellent properties of diamond to make faster transistors. A problem with modifying diamond surfaces, however, is the destructive thermal heating associated with conventional processing methods. The FEL's precise tuning, short pulses, and high power can help scientists cut through diamond without collateral heat damage and without disrupting the orderly crystalline lattice that makes diamond so desirable.

The FEL's potential ultimately will be fulfilled not by the nature of the technology, but rather by the vision of those who use it. By cooperating and exploring new ideas, Vanderbilt's FEL researchers will likely produce even more exciting developments in the future.

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What Does It Mean to You?

Free-electron lasers may allow surgeons to cut with far less damage to surrounding tissue and mammographers to obtain the clearest images to detect cancer, leading to better health care procedures.

What Does It Mean to Our Nation?

Free-electron lasers can address the challenges of human disease and disorders through new treatment techniques, potentially improving patient care and reducing medical costs.

Tech Trivia

By using the properties of electrons, scientists have been able to do all of the following except what?

A. Magnify the smallest objects
B. Observe distant galaxies
C. Prove the Big Bang theory
D. Investigate atomic structures

For the answer, see page 73.